PERSONAL TEMPO AND THE INTERRELATIONSHIPS OF VOLUNTARY AND MAXIMAL RATES OF MOVEMENT

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PERSONAL TEMPO AND THE INTERRELATIONSHIPS OF VOLUNTARY AND MAXIMAL RATES OF MOVEMENT*[1]

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A. PROBLEM

The present series of experiments, which in part had its origin from questions left unanswered in a previous study (43), is intended to investigate a group of related problems dealing with psychomotor tempo. The first and principal problem is whether or not the usual everyday or voluntary rate of movement is a unitary personal speed factor possessing intra-personal consistency. A related problem raises the same query with regard to maximal tempo, or the fastest rate of movement to which the subject can be motivated in a test situation. A third question is whether habituation resulting from repetition of performances will have any effect on specificity or generality of voluntary tempo. A fourth problem is the relationship between maximal rate of movement and everyday voluntary tempo. In the discussion to follow an attempt will be made to clarify the terminology and to make these issues more meaningful.

While implicit, it is a common popular assumption that individuals have a generalized velocity level for both gross movements and finer skeletal muscle adjustments so that they may be characterized on a continuous scale from fast to slow. The assumption which is here being subjected to examination is whether the relative speed ranking of a person remains fairly constant from one activity to another. Is our usual tempo a generalized psychomotor trait permeating the rate at which we execute any and all spontaneous movements, or is the rate determined more by the specific movements or acts concerned? A considerable body of data has accumulated on the closely

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related issue of whether specificity or generality holds for speeded performance or maximal tempo in the test situation. The problem with regard to everyday rate or voluntary tempo has been comparatively neglected, and what evidence has been reported has not been in complete accord.

A belief in a personal tempo has not been confined to popular assumption but has been held by such psychologists as Braun (9), Frischeisen-Köhler (32, 33), Guttmann (41), Meumann (66), Reymert (73), and Wu (89), among others. In various standardized test procedures the assumption is implicit that rate of movement of one body segment on one particular task is similar to any other segment or segments in combination on any other task. In the Downey *Will-Temperament* profile, for example, the position is defended, on some slight experimental evidence, that rate of writing a given expression is indicative of the general speed capacity of the individual. One reason for pursuing these problems is the conflicting nature of the experimental results obtained by various investigators. In these studies it is sought either to confirm or to refute the previous study where some doubts remained after its completion as to the effects which the varying *Einstellung* or set of the subjects had on the intercorrelations. Another objective is to alter subjects' instructions so that their orientation to the experimental tasks will approximate the set induced in the Braun work where generality findings were obtained (9).

Logically, the specificity-generality of speed of movement should have been one of the first, not one of the last, issues to be investigated. This is true because many problems relating to speed depend for their meaningfulness on whether or not tempo is a unitary trait. Such problems as the relationship between speed and intelligence, speed and accuracy, speed and memory, some of which have been more worked on experimentally than the specificity-generality issue, are, if the specifists are correct, without meaning when stated in such terms, without proper modifying conditions. Hence, the debated problem of the relationship between speed and intelligence is partly solved by restating the question in such a form as to inquire into the relationship between intelligence and a particular variety of speed task—whether primarily mental or motor, simple or complex, voluntary or maximal. Because of facile assumptions of speed generality, unfortunately many of the conclusions stated with regard to problems involving speed are equivocal or misleading.

The old problem of maximal specificity-generality will constitute a second subject of inquiry. Intercorrelations will be calculated in the hope of relieving some of the contradictions in the experimental history.

The third question for investigation is whether repetition of performances, or habituation, will have any effect on specificity or generality of voluntary tempo. The query arises out of the suggestion that generality, if it exists, may be due to the leveling of habit; in daily life carrying out the same acts over and over again may yield a greater generality and account for the apparent speed consistency which finds its place in the popular assumption of an individual personal tempo. Lauer (56) has been one of those to suggest that personal tempo may be due to habituation. Although the specific problem of the effect of repetition on voluntary speed has not been investigated, the effect of repetition on the intercorrelation of performances has been studied. The findings have been conflicting, and in any efforts to settle this point the collection of further data is desirable aside from the issue of speed specificity-generality *per se.*

The final major problem is the relationship between maximal and voluntary rate of movement. In addition certain less important issues will receive consideration. One is to study the influence of time spacing on the effect of repetition on voluntary rate specificity-generality. Other minor and more technical problems include the relationship between self-estimate for voluntary rate and actually measured voluntary rate, sex differences for voluntary tempo, and the relationship between voluntary rate and simple chronoscopic reaction time.

B. History

Most of the literature on the generality hypothesis is derived from work with maximal tempo and is somewhat ambitendent in results. Positive findings which a number of investigators have confirmed without exception are noticeably few considering the large volume of experimental effort. This condition is due not only to conflicting results but to the additional fact that there is no great overlap of methods and types of performance from one experimenter to another. Close analysis, however, will reveal certain conclusions which, since the field has not been thoroughly reviewed, may be briefly summarized.

Different kinds of reaction time yield high correlations (53)

even when different parts of the organism are reacting (73). Simple reaction time and discriminative rate of reaction give moderately high correlations (50, 53, 58, 70). Simple chronoscopic time is only slightly related to tapping (70, 72, 73, 75). The same low relationship holds between simple reaction and serial reaction time (7, 29, 42, 53). Intercorrelations of serial motor responses tend to be low but definitely positive (53). Rate of discrete reaction such as simple, discriminative, and word-association response is unrelated to serial reaction speed (53). Serial reaction is also only slightly correlated with rate of tapping (42). Different kinds of discriminative reaction are closely related (53). Even when various distractions and other complications are involved in discriminative response, substantial coefficients of correlation are obtained (28). Lanier found three different types of word-association related. Word-association time on the other hand is not related to either chronoscopic time or to rate of discriminative response according to most investigators (50, 53, 87), although this finding is contested by Hübel (47).

When two speed functions are correlated, their coefficient of correlation will be raised, other things being equal, if the functions are executed by members at the same end of the body such as right and left arms (18, 39, 60). Gates and Scott (39) presented some evidence that coefficients also tend to be higher when the same bodily side is involved, although the data of Campbell (18) on this point are negative. Somewhat similar higher-order mental functions often show high intercorrelations for speed of performance (20, 21, 36, 37, 48, 62, 64), but lower coefficients are reported by some authors (38, 49, 80). Intercorrelations for speed of decision tasks are inclined to be low but positive, suggesting not a unitary trait but some measure of consistency (30, 84, 85).

The one unifying differential which several authors think gives some understanding of intercorrelations of maximal speed measurements is the similarity or dissimilarity of the functions involved. This hypothesis which states that when the types of activity are similar the correlations tend to be high and that when they are widely disparate low correlations result would, if true, permit us to understand many of the conflicting claims of experimenters, for often the conclusions which favor a unitary speed factor are based on a narrow range of activities. Even bearing this precaution in mind, the ratio of results which favor specificity as against generality is at least two to one for maximal tempo. Lanier has suggested that whether a

given correlation between maximal speed functions will be high or not is determined not only by similarity of test content but by the postural or motor set. He believes, furthermore, that there is no evidence for a simple organic variable such as rate of neural conduction, as some have claimed, which would predispose an individual to a personal tempo. Many others who have performed maximal speed experiments have subscribed to the similarity hypothesis (19, 22, 29, 39, 60, 61). It is interesting to note how the similarity hypothesis as an explanation for contradictory results in speed measurements occupies an analogous position to the theory of identical elements in transfer of training.

When one attempts to construe the results of the few experiments on voluntary rate of movement one is puzzled both by the conflicting conclusions and by the varying instructions given subjects by the different experimenters. Some instructed reactors to work at a convenient speed (6, 9), one attempted to conceal the fact that speed was being measured (43), another concealed the speed measurements and speed intent most of the time but in a few instances told the subjects to proceed at a convenient rate (3), while in other studies the details of instruction were either obscure or unavailable (56, 89). Nevertheless, the number of experimental results slightly favors specificity (3, 43, 56) against generality (9, 89). In the correlations of both Wu (89) and Braun (9), moreover, there are exceptions to their usual finding of a high interrelationship between voluntary rate measurements. Allport and Vernon (3), while stating the non-existence of a personal tempo, favored the concept of group speed factors of moderate breadth. When their verbal, drawing, and rhythmic or tapping factors are examined, they may be explained without difficulty as involving little more than a relative similarity of performance.

C. Experiment I

1. *Method and Procedure*

The first experiment, which sought to obtain information on the specificity-generality of voluntary and maximal rates of movement and on their interrelationship, was carried out with 50 male undergraduates. The mean age was 19.0 with a range from 15 to 29. This group will hereafter be designated as Group *A*.

The tasks for Group *A* were divided into two parts. In the first the fact that speed measurements were being recorded was concealed,

but in the second part subjects were motivated in various ways to perform at maximal speed. The 12 performances which the subjects carried out at their chosen rate occupied the first half of the hour and the 12 maximal speed performances occupied the second half. The total time of the session was in the neighborhood of an hour and a quarter but sometimes was longer. Between tasks, a running stream of conversation was usually maintained in order to counteract monotony, put subjects at their ease, and allow them rest pauses between tasks. In rendering usual or spontaneous tempo possible in the laboratory situation, it is desirable to reduce the self-consciousness of the subject to a minimum, to create a relaxed and informal atmosphere, so that the reactor will neither feel strained in his movements nor constantly aware that he is being "mentally tested." Subjects were told in preliminary instructions that they were in no sense being examined but that only their usual, chosen, or convenient manner of responding was expected. Because previous workers and the present investigator in the earlier study had found a speed set prevalent in subjects, it was necessary to emphasize to subjects that they were not to move at their fastest rate but at that rate which was to them convenient and natural.

In the earlier study (43) speed was not mentioned but instead the object of the experiment was camouflaged by giving subjects plausible explanations of what might have been the purpose. Such a method, while having certain advantages in inducing the proper spontaneity with regard to tempo, also had certain disadvantages; probably the greatest single source of error was the varying *Einstellung* or set of the individual reactors. There was a variation evident in the interpretation of the instructions and a certain amount of uncertainty as to what was expected. Many asked if they were to perform as rapidly as possible and were reassured otherwise, but some who did not specifically inquire may have had a similar orientation. Braun (9), who has furnished the major evidence in favor of a unitary personal equation in everyday movement rate, gave his subjects instructions to proceed at their most convenient rate, which Allport and Vernon believe may have induced a constant set which would tend to make their subjects' mobility uniform. In order to avoid an inconstant set and to obtain evidence on the possible effect of the instructions in the Braun study, subjects were here given explicit instructions regarding the way in which they were to discharge their tasks. Individuals acting as subjects were kept in ignorance

regarding the purpose of the experiment even after the experimental hour was concluded.

In the first part of the hour the 12 performances, listed below, were carried out by the subjects with instructions to proceed at their usual or chosen rate. All performances were initiated with the remark: *"Whenever you are ready, you may begin"* instead of the more usual and abrupt *"Start!"* In the description of the tasks, the apparatus employed will be described under the task for which it was used. The more complicated apparatus designed for measuring head turn, body bend, and arm raising is illustrated in the accompanying wiring diagram (Figure 1). Where no apparatus is mentioned, a concealed stop-watch was employed to time performances.

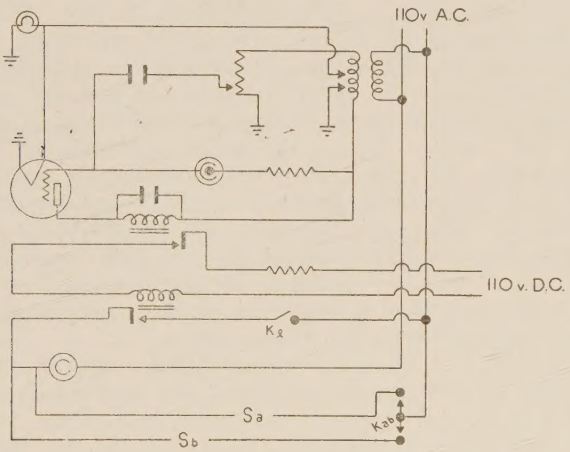

FIGURE 1

S_a is the subject switch in the circuit for measuring arm raising.
S_b is the subject switch in the circuit for measuring body bend.
K_{ab} is the experimenter's double-throw switch which controlled the arm raising and body bend circuits.
K_1 is the experimenter's switch for the photoelectric cell circuit.

Cranking. Subjects turned the hand-crank attached to a revolving drum ten times while the experimenter silently counted the revolutions of a notch on the drum.

Card sorting. Subjects sorted a pack of ordinary playing cards into four compartments according to suit. No corrections

were made for occasional errors and no notice was taken of such errors in the scoring.

Tapping. Subjects were instructed to tap at a voluntary rate on a double-plate tapping apparatus until the signal was given to stop. The time interval was 30 seconds and the score was the number of taps recorded electrically by the apparatus.

Head turn. A specially constructed leather helmet with a protruding arm was put on by the subject, who stood with his back toward a photoelectric cell that was raised on an adjustable platform. The photoelectric cell was slightly above the head level of the reactor so that the beam of light from the cell could be blocked by the protruding arm on the helmet as long as the head was stationary. The subject looked straight ahead at a mirror which reflected the light beam of the photoelectric cell and in so doing interrupted the beam with the protuberance on the helmet. The subject moved his head through an arc of 45 degrees till he fixated a strip of paper posted at the same horizontal level as his line of regard. After gazing at this long enough to retain a mental image, he moved his head back to look at the mirror a second time, thus interrupting the beam. The interval between the make and break of the beam was electrically recorded on a Cenco counter which was adjusted to give readings of 1/120 of a second. The whole procedure was illustrated first and then practiced once or twice by the subject so that the movements would be smoothly coördinated when the rate was recorded. (Electrical connections are shown in the wiring diagram.)

Body bend. Each subject was asked to be seated in a chair, to bend over and touch a padded bar with his forehead at the level of his eyebrows, and then return to a sitting posture. Previous to the recorded bend, the padded bar was adjusted horizontally to each subject. The dorsal surface of the subject in the upright position came in contact with a hinged board, and as the subject bent over the pressure on the board was released. With the release, a switch was closed and the time recorded on the Cenco counter. The act was practiced once or twice before being recorded. (Electrical connections in wiring diagram.)

Arm raising. A similar device was arranged with a stool on the right hand side of the chair. The surface of the stool served as an arm support. On the arm support were two hinged boards which either opened or closed a concealed circuit depending on whether the pressure of the resting arm was or was not being exerted on the upper board. The switch was

so arranged that when the reactor raised his arm to touch a horizontal bar the circuit was closed and when the reactor brought his arm back to the resting position the circuit was open. The angle through which the arm was raised was 90 degrees and the actual distance between the horizontal bar and the arm support was 22.5 inches. Timing was by Cenco counter. The act was practiced before being recorded. (Electrical connections in wiring diagram.)

Speed of decision. This test is Part I of the Downey Will-Temperament scale but was given here with a work-limit instead of a time-limit. It is made up of paired descriptive terms which are supposed to characterize the personal qualities of an individual. For each pair the reactor checked the one most characteristic of himself according to his own judgment. Subjects were cautioned not to require too great a length of time in their judgments but to check first impressions.

Writing. Subjects were instructed to copy in their ordinary handwriting the opening paragraph from an English translation of *Immensee* by Theodor Storm. The passage consisted of 45 words. The same set of pencils, which were always kept sharpened, was used by all subjects.

Reading. Subjects read aloud a more extended passage of 222 words from *Immensee* in their usual reading voice. The reading was repeated as a measure of reliability.

Counting. Subjects counted to 50 by twos and then backward to two again. Repeated for reliability.

Patting. While seated with their feet resting on a horizontal support, subjects clapped their hands twice and then struck or patted the appropriate knee with the appropriate hand (right hand-right knee, left hand-left knee). This rhythmic action was repeated continuously 20 times. The count was kept by the experimenter. The patting was illustrated first and then practiced until smooth coördination was attained before a measurement was taken. Repeated for reliability.

Walking. The subject was asked to walk as nearly as possible in his everyday manner with a chalk-line as a guide. It was only required of the subject that with each step some part of the foot touch the chalk-line. The line was in the shape of a squared-out S with the following dimensions: 23′ x 10″ x 23′ x 10″. So that there would be no ambiguity, the experimenter illustrated the beginning of the walk as well as what was permissible in executing turns. Repeated for reliability.[1]

[1]Repeat reliability correlations were obtained for all performances where

The performances employed both in the voluntary and the maximal speed tasks were selected so that there would be a broad sampling of activities, including a variety of cognitive, vocal, graphic, sensorimotor, simple motor, and locomotive activities, usually with more than one representative of each type in order to test the similarity hypothesis. In the voluntary speed tasks widely different muscle groups were utilized, including leg and trunk (walking), torso (body bend), head and neck (head turn), speech musculature (counting, reading) and hand and arm (tapping, patting, cranking, arm raising, card sorting, writing). In the voluntary speed tasks the range extended from simple motor and locomotive functions to the more complex cognitive.

Required of the same subjects immediately following the voluntary speed performances were 12 maximal speed tasks. It was at once emphasized and re-emphasized with each task that subjects should perform at their fastest possible rate. Motivation was supplied by comments and by comparing the individual's score following each performance with the other scores. Reactors were allowed to rest if fatigued before the conclusion of the hour. Timing was by stop watch, which was no longer concealed but brought conspicuously into sight.

Rossolimo puzzle. A particularly difficult Rossolimo picture puzzle was set before the subjects for solution. Toward the end of the hour this test was repeated for reliability.

Finger dexterity. The *Finger Dexterity* test of O'Connor was modified so that instead of 100 holes there were 32 holes into each of which three pins were put with the pin head placed up. The score was the number of holes completed correctly in two minutes. Repeated for reliability.

(*a*) no previous reliabilities existed in the literature and (*b*) where reliabilities had not already been found in the previous study where some of the identical performances had been used. For the reliabilities of cranking, tapping, arm raising, body bend, and head turn see (43, Table 1). For speed of decision reliabilities in the literature have varied between .49 and .92 (24, 85), for card sorting between .66 and .88 (69, 83, 85), for substitution tests between .70 and .95 (19, 35, 58), and Burt for multiplication found .55 (13, 14). Original reliability data obtained here were: writing .91±.02, reading .89±.02, patting .93±.01, omitted letter .79±.04, finger dexterity .57±.06, walking .80±.04, counting .89±.02, and Rossolimo puzzle .16±.09. The Rossolimo puzzle figure is not very meaningful because of the nature of the task; high reliability would not be expected for a performance depending on "insight" so much as a picture puzzle. In general retest reliabilities have almost without exception been high in the field of speed measurements.

Substitution. A symbol substitution test in the *Johns Hopkins Psychological Test Series* was employed. For explanation and practice another form of the test in the same series was used. The scoring was the number completed in two minutes.

Multiplication. Eight multiplication examples involving three digits were placed before the subjects who were instructed to work primarily for speed, paying some attention however to accuracy. The score was the time required to finish. No penalty was exacted for mistakes.

Speeded writing. The same *Immensee* passage was used as in the voluntary speed performances, except this time the subject was asked to write as rapidly as possible regardless of the quality of the penmanship.

Speeded reading. The *Immensee* passage read in the first part of the hour was employed with directions altered. The only requirement was that each word be distinct and that there be no omissions. The score was the time required.

Omitted letter. Another test in the Johns Hopkins Series, the omitted letter, requires considerable ideation and has been used in intelligence test batteries. It consists of two columns of words, the one made up of rather difficult English words and the second of letters in the same words rearranged in random fashion so that the result is a nonsense-word. One letter in the corresponding word of the first column moreover was omitted in the second column. The subject was required to check in the first column the letter missing in the second column. The number of words finished in two minutes was the score. Repeated for reliability.

Speeded patting. The same patting performance used before was repeated with speed directions. So that the final execution would be smooth and well-coördinated, subjects were allowed to practice. Forty pats were required.

Speeded card sorting. Except that subjects were cautioned against making errors but were told to proceed at their most rapid rate, the task was the same as before.

Speeded tapping. The same as before except for altered instructions with regard to speed.

Speeded cranking. The same task as in the first part of the hour except that 15 turns of the crank were required of reactors. The experimenter first illustrated maximal rate.

Reaction time. A standard piece of apparatus, the Dunlap chronoscope, was used to measure simple reaction time. The chronoscope operated off a 110 v. A.C. source with a G.E. tungar rectifier in the circuit. Since auditory and visual reaction

time are known to correlate highly, only the auditory rate was measured. A bell signal warned the subject before the auditory stimulus occurred. A preliminary adjustment period during which the subject reacted until his scores reached a fair constancy preceded the actual recordings. The final score was an average of several reactions. The Dunlap chronoscope yields readings in sigma units.

When a logical or a priori arrangement of maximal rate tasks is made, they would appear to fall into several categories. Thus the Rossolimo puzzle, the omitted letter, and multiplication suggest higher-order intellectual or cognitive functions; the finger dexterity, card sorting, and substitution tasks might be called sensori-motor functions; while tapping, patting, cranking, and possibly reaction time might be classed as simple motor reactions. The selection of activities was so planned that tasks which were logically similar might be expected to yield correlation clusters if it be true that speed tasks with common elements in their content yield high correlations.

2. *Results*

a. Specificity-generality for voluntary tempo. Inspection of Table 1 demonstrates a rather thoroughgoing specificity for voluntary tempo, characterized by low coefficients for the majority of the interrelationships and by several negative correlations. Intermingled with these specificity results are some substantial coefficients which are statistically reliable. Such findings are in general not out of harmony with the earlier study. The larger number of high coefficients and the fewer negative values in the present experiment might have been anticipated because of the larger number of functions, the altered instructions to the subjects, and the deliberate inclusion of functions which would permit the emergence of correlation clusters if such exist. It may be observed that altering instructions so that they would accord with Braun's directions to his subjects failed to produce definite and clear-cut generality.

Specificity is indicated by the average columnar r's which vary between $-.05\pm.10$ and $.31\pm.09$ and by the average of all intercorrelations, $.16\pm.09$. If we exclude correlations with reaction time, which is non-voluntary, the average is stepped up to $.20\pm.09$ with the columnar coefficients lying between $.09\pm.09$ and $.34\pm.08$. (Since reaction time is not a voluntary but a maximal rate task,

TABLE 1

COEFFICIENTS OF CORRELATION FOR GROUP *A* ON VOLUNTARY TEMPO

	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Head turn		.46 ±.08	.45 ±.08	.04 ±.10	.11 ±.09	.05 ±.10	.16 ±.09	—.06 ±.10	.30 ±.09	—.05 ±.10	.15 ±.09	.25 ±.09	—.09 ±.09
2. Arm raising			.61 ±.06	.05 ±.10	.25 ±.09	.13 ±.09	.33 ±.08	.25 ±.09	.44 ±.08	—.16 ±.09	—.12 ±.09	.15 ±.09	—.27 ±.09
3. Body bend				.11 ±.09	.35 ±.08	.15 ±.09	.20 ±.09	.19 ±.09	.49 ±.07	.09 ±.09	.13 ±.09	.52 ±.07	—.15 ±.09
4. Counting					.29 ±.09	.16 ±.09	.04 ±.10	—.03 ±.10	.27 ±.09	.15 ±.09	.58 ±.06	.18 ±.09	.29 ±.09
5. Speed of decision						.10 ±.09	.18 ±.09	.33 ±.08	.52 ±.07	.07 ±.09	.12 ±.09	.36 ±.08	—.03 ±.10
6. Walking							.07 ±.09	—.26 ±.09	.28 ±.09	.08 ±.09	.12 ±.09	.19 ±.09	.21 ±.09
7. Cranking								.46 ±.08	.52 ±.07	.13 ±.09	.12 ±.09	.20 ±.09	—.40 ±.08
8. Card sorting									.34 ±.08	.25 ±.09	—.01 ±.10	.18 ±.09	—.23 ±.09
9. Tapping										.02 ±.10	.12 ±.09	.47 ±.07	.00 ±.10
10. Writing											.29 ±.09	.07 ±.09	—.07 ±.09
11. Reading												.27 ±.09	.09 ±.09
12. Patting													.09 ±.09
13. Reaction time[1]													
Average	.15 ±.09	.18 ±.09	.26 ±.09	.18 ±.09	.22 ±.09	.11 ±.09	.17 ±.09	.12 ±.09	.31 ±.09	.07 ±.09	.16 ±.09	.24 ±.09	—.05 ±.10

[1]Maximal rate.

hereafter in the discussion of voluntary tempo the correlations with reaction time will be ignored.) If four times the probable error be taken as the measure of statistical reliability, there are 16 coefficients or 24 per cent of the total 66 correlations for voluntary tempo which may be considered as reliable. There are 59 positive and seven negative r's in the entire table. The 16 coefficients which pass the criterion for statistical reliability are given below with their probable errors:

Arm raising and body bend	.61±.06
Counting and reading	.58±.06
Body bend and patting	.52±.07
Tapping and cranking	.52±.07
Tapping and speed of decision	.52±.07
Tapping and body bend	.49±.07
Tapping and patting	.47±.07
Cranking and card sorting	.46±.08
Head turn and arm raising	.46±.08
Head turn and body bend	.45±.08
Tapping and arm raising	.44±.08
Speed of decision and patting	.36±.08
Speed of decision and body	.35±.08
Tapping and card sorting	.34±.08
Arm raising and cranking	.33±.08
Speed of decision and card sorting	.33±.08

We may anticipate by saying that Groups *B* and *C* in Experiment II during their first practice day perform some of the same activities as Group *A*. Their intercorrelations are presented in Tables 6 and 8 and are useful in checking findings for Group *A*. If we were to demand as criterion of consistency that a correlation which is statistically reliable for Group *A* be reliable also for Groups *B* and *C*, it would be found that of the 10 reliable coefficients listed above which were calculated between performances repeated in Groups *B* and *C* there is only one which is reliable throughout all three tables (tapping-patting). However, because of the small number of cases in Groups *B* and *C* we may return to Table 1 to examine the significant positive correlations, taking them for the moment at their face value. This procedure is desirable because of the possibility of correlation clusters within the specificity frame and in view of the common opinion which explains high coefficients by similarity of performances when the correlation matrix as a whole is dominated

by specificity. Such methods as Thurstone factor analysis which might seem indicated were not employed because factors were of only incidental interest and the experiment was not planned so as to yield data which would satisfy the conditions for factor analysis. Thus, as the data stand, there is too small a number of variables for the heterogeneity contained therein.

When the 16 positive and statistically reliable correlations are considered in relation to the similarity hypothesis, most but not all these correlations might be explained with some effort on the basis of common elements. Thus the interrelationships between head turning, arm raising, and body bending might be regarded as simple motor adjustments frequently executed as part of a larger context in everyday life, and the correlation between counting and reading could be explained as owing to the fact that the speech musculature was involved in both functions. The positive correlation of cranking with arm raising and card sorting and many of the correlations with tapping could be explained by the common involvement of the musculature of the preferred hand and arm, but it would be somewhat far-fetched to speak of the employment of the arm muscles as a common element in the correlations of speed of decision with card sorting, tapping, and patting. The hypothesis of similarity when interpreted as logical similarity further breaks down for the correlation of tapping with body bend and of body bend with speed of decision and patting where any perception of commonality is evasive.

For the sake of more thorough analysis inquiry into the similarity hypothesis may be pursued still further. If head turning, arm raising, and body bending are simple everyday functions which may be expected to cluster, so also is rate of walking which is not highly correlated with the other three functions. If the functions which involve the use of the hand-arm muscles were to constitute a cluster or group factor on the basis of similar musculature, then arm raising, cranking, card sorting, patting, tapping, and writing should all intercorrelate significantly. Actually the mean intercorrelation is only slightly higher than the rest of the table (.24).

Allport and Vernon (3) postulated from their data group factors which they designated as verbal, drawing, and rhythmic. If verbal be defined as the factor comprising functions which involve the manipulation of words, our data include three examples: writing, reading, and speed of decision. Intercorrelations of these functions are low. Some of the voluntary tempo of Braun (9) deals with

verbality and gives additional evidence on the possible existence of such a factor. His rank-order coefficients of .59 between singing and writing, .39 between singing and copying, and .59 between singing and writing suggest a cluster, but coefficients for singing and reading (.23), writing and reading (.22), and copying and reading (.28) are less convincing. It would appear that Allport and Vernon may have overdrawn the breadth of their hypothetical verbal factor. The same authors have also postulated a rhythmic factor which, upon inspection of its components, turns out to be primarily a tapping factor. The present data include tapping, patting, and cranking as rhythmic functions in the repetitive sense of the term as used by these authors. The correlation of tapping with patting is .47±.07, tapping with cranking .52±.07, and cranking with patting .20±.09. These findings are more or less in conformity with the hypothesized rhythmicity factor, although more data are necessary for confirmation.

While most but not all the reliably high coefficients can be explained in terms of logical similarity, there are other coefficients in Table 1 which are either low or negative but which are between functions that seem from an a priori standpoint to involve common elements. Apparently the similarity hypothesis is in need of modification. While results favor specificity there are suggestions of correlation clusters or group factors within the specificity but not group factors always based on a strictly predictable or logical similarity hypothesis usually assumed, which must be given a more imaginative or dynamic rendering which will be more in terms of process or function, with due regard for the level of complexity, and less in terms of static classification of the externals of tasks with their easily analyzable common elements. It is equivalence for the organism, not a priori or logical similarity, which determines the size and sign of speed interrelationships for voluntary tempo. For similarity we should look not only to the externals of performances but to the functional state of the neuromuscular system because functional equivalence is equivalence in the organism—not such an equivalence in the tasks as would yield to objective analysis of common elements and prediction therefrom of correlations. There is no point to point correspondence between apparent similarity or equivalence of tasks and actual functional equivalence for the individual. What constitutes functional equivalence is undetermined, but the external similarity of tasks to be performed could at best be only one factor.

Despite the specificity findings there is the possibility that there might be a few individuals who are definitely consistent in tempo and who would be masked by the "averaging effect" of the correlation technique. To inquire into this possibility, the voluntary tempo scores of all 50 subjects for all variables were converted into rank-orders and psychograms for each subject were charted. After a detailed consideration of the rank-order ranges for each individual and various other criteria of consistency, there were found two subjects who were clearly consistent, falling within a narrow rank-order range. If a quite liberal interpretation of "consistency" were made, there were about nine other subjects who showed a fair consistency. All the remaining subjects showed the completely erratic rank-order profiles that would be expected on the basis of the correlations findings.

The minor technical problem of the relationship between chronoscopic reaction time and voluntary tempo is answered by an inspection of Table 1 where correlations were either low or negative. The average r between reaction time and the voluntary tempo variables was $-.05 \pm .10$.

b. Specificity-generality for maximal tempo. For speeded performances the results, which are given in Table 2, are if anything more specific than the results for voluntary rate. The range of coefficients is between $-.40 \pm .08$ and $.51 \pm .07$; the average columnar correlations lie between $-.09 \pm .09$ and $.24 \pm .09$; and the average for the entire table is $.15 \pm .09$. Fifty values are positive, 15 negative, and one is zero. Of the table of 66 correlations 13 coefficients are statistically reliable, of which one is negative. These correlation coefficients with their probable errors are given below:

Speeded patting and speeded tapping	$.51 \pm .07$
Speeded cranking and speeded tapping	$.48 \pm .07$
Speeded writing and finger dexterity	$.48 \pm .07$
Speeded patting and speeded cranking	$.44 \pm .08$
Speeded reading and multiplication	$.39 \pm .08$
Speeded reading and speeded writing	$.38 \pm .08$
Speeded card sorting and substitution	$.38 \pm .08$
Speeded card sorting and finger dexterity	$.36 \pm .08$
Speeded cranking and multiplication	$.35 \pm .08$
Speeded tapping and finger dexterity	$.34 \pm .08$
Speeded card sorting and multiplication	$.33 \pm .08$
Speeded writing and Pyssolimo puzzle	$-.40 \pm .08$

TABLE 2

COEFFICIENTS OF CORRELATION FOR GROUP *A* ON MAXIMAL TEMPO

	1	2	3	4	5	6	7	8	9	10	11	12
1. Puzzle		—.26 ±.09	—.06 ±.10	.27 ±.09	—.04 ±.10	.08 ±.09	—.03 ±.10	—.30 ±.09	.00 ±.10	—.40 ±.08	—.23 ±.09	—.03 ±.10
2. Finger dexterity			.16 ±.09	.22 ±.09	.18 ±.09	—.06 ±.10	.22 ±.09	.36 ±.08	.34 ±.08	.48 ±.07	.35 ±.08	.10 ±.09
3. Substitution				.25 ±.09	.23 ±.09	—.01 ±.10	.19 ±.09	.38 ±.08	.31 ±.09	.12 ±.09	.21 ±.09	.24 ±.09
4. Multiplication					.24 ±.09	.13 ±.09	.35 ±.08	.33 ±.08	.11 ±.09	.03 ±.10	.39 ±.08	.29 ±.09
5. Omitted letter						—.11 ±.09	—.02 ±.10	.27 ±.09	.23 ±.09	.11 ±.09	.28 ±.09	.24 ±.09
6. Reaction time							.01 ±.10	—.27 ±.09	—.14 ±.09	.02 ±.10	.05 ±.10	—.15 ±.09
7. Speeded cranking								.33 ±.08	.48 ±.07	.13 ±.09	.28 ±.09	.44 ±.08
8. Speeded card sorting									.29 ±.09	.22 ±.09	.19 ±.09	.25 ±.09
9. Speeded tapping										.17 ±.09	.22 ±.09	.51 ±.07
10. Speeded writing											.38 ±.08	.22 ±.09
11. Speeded reading												.22 ±.09
12. Speeded patting												
Average	—.09 ±.09	.19 ±.09	.18 ±.09	.24 ±.09	.15 ±.09	—.04 ±.10	.22 ±.09	.19 ±.09	.23 ±.09	.13 ±.09	.21 ±.09	.21 ±.09

When the statistically reliable coefficients are examined, we find similarity in some but not in all. Many of the coefficients are between functions involving the hand-arm musculature. In fact, if all the functions which utilize the hand-arm musculature in a major way—finger dexterity, cranking, card sorting, tapping, writing, and patting—are examined, one finds all their intercorrelations are positive and that the mean inter-*r* is .30, which is twice as large as the mean inter-*r* for the entire table. The coefficient for reading and writing suggests that simple serial verbal manipulations may be related, but these are the only variables in that category; when each is related to a complex verbal manipulatory activity like the omitted letter test, the relationship turns out to be low (.11±.09 and .28±.09).

One might have anticipated that complex higher-order cognitive tasks such as the Rossolimo puzzle, multiplication, and the omitted letter test would be definitely related. The anticipation dissolves, however, when we discover the intercorrelations to be —.04±.10, .24±.09, and .27±.09. When the more familiar laboratory sensorimotor group of functions such as card sorting, tapping, substitution, and finger dexterity are examined, there is somewhat more evidence of a cluster (mean inter-*r* .31). The speeded graphic group of activities which includes substitution, multiplication, omitted letter, and writing fails to cluster (mean inter-*r* .16). The speeded rhythmic group which includes tapping, cranking, and patting again shows an internally consistent positive relationship which is relatively high (.51±.07, .48±.07, and .44±.08).

When each subject's scores were converted into rank-orders and profiled for a study of possible exceptional persons who consistently performed at their individual speed level, three such subjects were found out of the total of 50 reactors. There were also three other individuals who were possible candidates for consistency in that they usually but not always fell within a fairly small rank-order range.

c. Relationship between voluntary and maximal tempo. Table 3 gives the coefficients of correlation between performances of the same function under the two conditions of voluntary and maximal rates. The correlations are for Group *A* with $N = 50$. If we may rely on these few coefficients, the relationship between voluntary and maximal rates varies considerably with the specific function but on an average is positive and statistically reliable although not high (mean *r* .37±.08).

TABLE 3
COEFFICIENTS OF CORRELATION BETWEEN VOLUNTARY AND MAXIMAL RATE PERFORMANCES OF THE SAME TASK BY GROUP *A*

	r PE
Card sorting	.17±.09
Tapping	.35±.08
Writing	.46±.08
Reading	.70±.08
Cranking	.09±.09
Patting	.36±.08
Average	.37±.08

d. Relationship between self-estimated and measured voluntary tempo. Individuals in Group *A* after the termination of the first half of Experiment I rated themselves as fast, medium, or slow as shown by their everyday activity. The object was to discover how well an individual's self-estimate of everyday or voluntary rate would correspond with his relative standing in performances on which voluntary rate measurements were made. Twenty subjects rated themselves as fast, 17 medium, and nine slow. The three groups were averaged separately for the determination of central tendency (mean) and for dispersion around the central tendency (standard deviation). Results are presented in Table 4. The comparison of means between the Fast Group and the Slow Group shows the Fast Group to be superior in rate in all 12 functions. For the Medium and Slow Groups, in 11 out of 12 functions the Medium Group was superior. For the Fast and Medium Groups, the former was superior in nine out of 12 functions. The mean differences favoring the Fast and Medium Groups over the Slow Group are much more convincing than the mean differences favoring the Fast over the Medium Group.

When overlapping distributions are taken into account and the critical ratios inspected, it is found that for those comparisons of the Fast and Slow Groups which favor the Fast Group seven out of 12 mean differences are statistically significant if a critical ratio of 2.2, or 98.6 chances out of a 100, be considered as the criterion. If a critical ratio of 2.7, or 99.7 chances out of a 100, be the criterion, then the number of significant differences drops to three. For the mean comparisons which favor the Medium against the Slow Group when 2.2 is the criterion, five out of the 11 are statistically significant, but only two when the critical ratio criterion is 2.7. For the mean

TABLE 4
COMPARISON OF SELF-ESTIMATED AND MEASURED VOLUNTARY TEMPO FOR GROUP *A*

Task	Group	Rate rank order	Mean	*SD*	Groups compared	Critical ratio	Chances in 100 difference is a true difference
Cranking	Fast	2	29.9	7.8	*F* and *S*	1.7	96
	Medium	1	28.3	5.1	*F* and *M*	.8	79
	Slow	3	36.0	9.6	*M* and *S*	2.3	99
Card sorting	Fast	2	72.3	8.7	*F* and *S*	2.2	99
	Medium	1	70.4	13.1	*F* and *M*	.5	69
	Slow	3	82.3	12.3	*M* and *S*	2.3	99
Tapping	Fast	1	48.85	12.54	*F* and *S*	3.6	100
	Medium	2	48.50	15.82	*F* and *M*	1.	54
	Slow	3	35.28	7.34	*M* and *S*	2.9	100
Head turn	Fast	1	2.314	.903	*F* and *S*	.9	82
	Medium	2	2.358	.762	*F* and *M*	.2	58
	Slow	3	2.573	.590	*M* and *S*	.8	79
Arm raising	Fast	1	2.441	.614	*F* and *S*	2.4	99
	Medium	2	2.712	.839	*F* and *M*	1.1	86
	Slow	3	2.993	.541	*M* and *S*	1.0	84
Body bend	Fast	1	3.607	.780	*F* and *S*	3.0	100
	Medium	2	3.836	.625	*F* and *M*	1.0	84
	Slow	3	4.340	.525	*M* and *S*	2.2	99
Speed of decision	Fast	1	52.6	18.7	*F* and *S*	2.5	99
	Medium	2	62.5	31.4	*F* and *M*	1.1	86
	Slow	3	75.8	24.9	*M* and *S*	1.2	88
Writing	Fast	2	103.6	16.2	*F* and *S*	2.4	99
	Medium	1	98.5	13.9	*F* and *M*	1.0	84
	Slow	3	114.8	9.4	*M* and *S*	3.5	100
Reading	Fast	1	68.3	7.1	*F* and *S*	.5	69
	Medium	3	71.6	9.3	*F* and *M*	1.2	88
	Slow	2	69.9	7.9	*M* and *S*	.5	69
Counting	Fast	1	28.8	3.4	*F* and *S*	1.5	93
	Medium	2	31.2	5.8	*F* and *M*	1.5	93
	Slow	3	31.8	5.4	*M* and *S*	.3	62
Patting	Fast	1	18.9	3.8	*F* and *S*	3.3	100
	Medium	2	22.3	3.6	*F* and *M*	2.7	100
	Slow	3	23.1	2.6	*M* and *S*	.6	73
Walking	Fast	1	21.5	3.9	*F* and *S*	1.8	96
	Medium	2	21.9	2.8	*F* and *M*	.4	65
	Slow	3	23.9	2.9	*M* and *S*	1.6	94

comparisons which favor the Fast over the Medium Group, whether 2.2 or 2.7 is taken as the criterion, there is but one significant

difference out of eight. The table shows that some of the other differences approach true differences. That differences of the means are better than chance in the great majority of the comparisons, especially between Fast and Slow and between Medium and Slow Groups, may be seen from the column legended *"Chances in 100 the difference is a true difference."*

Because of the shortcomings of the critical ratio technique with a limited number of cases and as a supplementary analytical technique, the correlation method was applied to the data. Because one variable was arranged in three classes or categories instead of being distributed as scores on a continuous scale, a substitute method for Pearson *r* was necessary. The Yule simplification of the Pearson coefficient of mean square contingency was selected (34). The scores on the second or measured tempo variable were arranged into five classes so that the tables for correlating the self-estimates with each voluntary rate function was each 3 x 5 fold. Since the highest value that *C* can take when a 3 x 5 fold table is used is .85, the simple device of dividing the raw *C* by its maximum possible value was employed to make the *C* values approximate Pearson *r*. More refined corrections are possible but this rough method suggested by Odell (68) was considered adequate for present purposes.

The *C*'s which were obtained between estimate and laboratory scores on the 12 voluntary rate functions are given in Table 5. All coefficients show definite positive relationships with an average corrected *C* of .51. These findings confirm the critical ratio analysis.

TABLE 5

COEFFICIENTS OF CONTINGENCY BETWEEN SELF-ESTIMATED AND MEASURED VOLUNTARY TEMPO FOR GROUP *A*

	C	Corrected
Cranking	.44	.52
Card sorting	.56	.66
Tapping	.47	.55
Head turn	.43	.51
Arm raising	.46	.54
Body bend	.47	.55
Speed of decision	.41	.48
Writing	.31	.36
Reading	.44	.52
Counting	.45	.53
Patting	.48	.56
Walking	.30	.35
Average	.44	.51

The general trend of the results favors the conclusion that individuals can rate themselves for voluntary tempo much better than chance expectation, although this trend is least marked between the Fast and Medium Groups. In other words, the Fast and Medium Groups knew that they were not the slowest and persons who called themselves slow were likely to be correct in their estimate according to laboratory measurements, but the distinction between the Fast and Medium Groups failed to hold with any great constancy or with significant group differences from one variable to another. Apparently too many people who belonged to the medium category rated themselves fast. Confirmation of the apparent fact that subjects were eager to rate themselves fast but hesitant about rating themselves slow is the skewed distribution favoring the fast rating. Since speed is probably considered desirable in our culture, the skewed distribution of the ratings is not surprising in light of the common finding with self-rating studies that persons tend to overrate themselves for desirable traits.

These results demonstrate not only that self-estimates are better than chance but indicate that individuals cannot judge their speed level in relation to other individuals with any fine degree of accuracy. In this indication lies a possible cue to the implicitly assumed belief in voluntary rate generality. If individuals cannot rate themselves with accuracy it is improbable that they can rate the relative speed level of other individuals with any greater accuracy; hence the persistence of the popular assumption of a generalized voluntary tempo for everyone. The actual existence of a few persons who are fairly consistent in their rate of reaction may also contribute to the perpetuation of the belief.

D. Experiment II

1. *Method and Procedure*

In Experiment II the primary interest was in studying the effect of repetition of performances, or habituation, on voluntary speed specificity-generality. Since many of the laboratory performances were new to the subjects whereas activities in daily life are practiced, it had been suggested that habituation might make for greater generality in voluntary tempo. In addition, and quite apart from work on speed specificity-generality, certain investigators have maintained that repetition of tasks raises the intercorrelations of those

tasks; although this claim has been contested. Hollingworth was the first to find a uniform augmentation of correlation values from prolonged practice (45, 46). Several have found this augmental effect up to a certain point in the practice but after further repetition there would be either a maintenance of the same level for the correlation values or a decline (12, 49, 51). McNemar (65) has presented some evidence favoring the Hollingworth hypothesis, but others have discovered little evidence that a person will change his relative ranking with prolonged practice (9, 42) while Muscio (67) and Buxton and Humphreys (15, 16) have reported negative results for motor performance.

Experiment II was composed of two groups of subjects who hereafter will be designated as Group *B* and Group *C*.

Group *B* comprised 20 subjects, evenly divided for sex. The mean age was 21.0 with a range from 17 to 28. The 10 tasks performed were chosen among the voluntary speed tasks of Group *A*. They were cranking, tapping, head turn, arm raising, body bend, writing, reading, counting, patting, and walking. The instructions and all other conditions were equivalent to those listed for Group *A* during the first (voluntary rate) half of Experiment I. Since for both Groups *B* and *C* the purpose was to discover the effect of repetition of performances on the intercorrelations of voluntary speed activities, it was arranged that Group *B* come for a repetition of the same experimental tasks for six consecutive days.

Twenty subjects, evenly divided for sex, constituted Group *C*. The mean age was 20.6 and the range was from 15 to 27. The same 10 voluntary speed tasks employed in Group *B* were used for Group *C* under the same conditions except that, instead of repeating the experiment on six consecutive days, Group *C* repeated the experiment over a period of six weeks on the same day of the week. The only difference, therefore, between Groups *B* and *C* was that the time interval for the former group was one day and for the latter seven days.

While the objection may be raised that six practice periods are not sufficient to bring out the maximal effect from repetition, six practice days were all that were feasible. If dependence may be put on previous work by investigators who have claimed an augmental effect on correlations from practice, a definite and noticeable effect should be observed by the sixth practice period. Moreover, some have shown that following very extended practice the correlations

begin to decline or become irregular after once having risen to their maximal values; this effect may be due to interference from subjective factors such as an understandable boredom on the part of subjects.

2. *Results*

a. Effect of repetition on voluntary tempo intercorrelations. The problem is principally whether a large numerical increase or augmental trend in voluntary tempo correlations occurs as a result of practice, for if this be true the apparent generality of voluntary tempo in daily life could be attributed to habituation. This hypothetical effect may be studied by comparing the daily and weekly groups for the first and final practice days (*B-I* and *C-I* with *B-VI* and *C-VI* in Tables 6 to 9). If the hypothesis that generality is due to habituation holds, then the overwhelming majority of correlations in *B-VI* and *C-VI* should be much closer to 1.0, or positive unity, than the same *r*'s in *B-I* and *C-I*. This hypothesis will be designated as Hypothesis I.

A second and more remote possibility is that practice will cause correlations to become larger in numerical value regardless of sign. In this event positive *r*'s will approach 1.0 and negative *r*'s will approach —1.0, or negative unity. This is a possible interpretation for the opinion, already discussed, that intercorrelations after continued practice will be larger than on the initial performance. This hypothesis will be designated as Hypothesis II.

A third possibility is the negative finding that any change in coefficients from the first to the sixth practice day may be attributed to chance and variable factors such as experimental error and quotidian variation in which event correlational fluctuations in the experimental comparisons should be of the same order of magnitude as the correlational fluctuations from *B-I* to *C-I*.

Tables 6 through 9 show not only the individual but average columnar correlations. For the everyday group on the first day the average *r* for the entire table is .24±.14 and on the final day .36±.13, which is a definite increase. The range of the columnar average *r*'s on the first day is from .10±.15 to .41±.13 and on the final day from .12±.15 to .50±.11. The average *r* for the weekly group on the first day is .18±.15 and on the final day .17±.15, which is almost identical. The range of the columnar average *r*'s on the first day is from —.02±.15 to .26±.14 and on the final day

TABLE 6

COEFFICIENTS OF CORRELATION FOR GROUP *B* ON VOLUNTARY TEMPO ON THE FIRST PRACTICE DAY (DAILY GROUP)

	1	2	3	4	5	6	7	8	9	10
1. Cranking		.07 ±.15	.38 ±.13	.39 ±.13	.45 ±.12	—.18 ±.15	.09 ±.15	—.20 ±.14	.40 ±.13	.17 ±.15
2. Tapping			.03 ±.16	.19 ±.15	.42 ±.12	.41 ±.13	.40 ±.13	.52 ±.11	.63 ±.09	.43 ±.12
3. Head turn				.15 ±.15	.41 ±.13	—.16 ±.15	—.27 ±.14	.23 ±.14	.32 ±.14	.01 ±.15
4. Arm raising					.45 ±.12	.23 ±.14	.15 ±.15	—.07 ±.15	.42 ±.12	.53 ±.11
5. Body bend						.39 ±.13	.11 ±.15	.00 ±.15	.48 ±.12	.35 ±.13
6. Writing							.73 ±.07	.45 ±.12	.19 ±.15	.01 ±.15
7. Reading								.44 ±.12	.43 ±.12	—.15 ±.15
8. Counting									.42 ±.12	—.02 ±.15
9. Patting										.38 ±.13
10. Walking										
Average	.17 ±.15	.34 ±.13	.12 ±.15	.27 ±.14	.34 ±.13	.23 ±.14	.21 ±.14	.10 ±.15	.41 ±.13	.19 ±.15

TABLE 7

COEFFICIENTS OF CORRELATION FOR GROUP *B* ON VOLUNTARY TEMPO ON THE SIXTH PRACTICE DAY (DAILY GROUP)

	1	2	3	4	5	6	7	8	9	10
1. Cranking		.38 ±.13	.48 ±.12	.58 ±.10	.42 ±.12	.10 ±.15	.35 ±.13	.32 ±.14	.71 ±.07	—.02 ±.15
2. Tapping			.29 ±.14	.53 ±.11	.68 ±.08	.41 ±.13	.39 ±.13	.63 ±.09	.61 ±.09	.36 ±.13
3. Head turn				.63 ±.09	.58 ±.10	.20 ±.14	.04 ±.15	.17 ±.15	.27 ±.14	.03 ±.15
4. Arm raising					.72 ±.07	.40 ±.13	.48 ±.12	.36 ±.13	.42 ±.12	.12 ±.15
5. Body bend						.33 ±.13	.28 ±.14	.52 ±.11	.49 ±.11	.50 ±.11
6. Writing							.41 ±.13	.73 ±.07	.17 ±.15	.06 ±.15
7. Reading								.44 ±.12	.30 ±.14	—.03 ±.15
8. Counting									.46 ±.12	.15 ±.15
9. Patting										—.06 ±.15
10. Walking										
Average	.37 ±.13	.48 ±.12	.30 ±.14	.47 ±.12	.50 ±.11	.31 ±.14	.30 ±.14	.42 ±.12	.37 ±.13	.12 ±.15

TABLE 8

COEFFICIENTS OF CORRELATION FOR GROUP *C* ON VOLUNTARY TEMPO ON THE FIRST PRACTICE DAY (WEEKLY GROUP)

	1	2	3	4	5	6	7	8	9	10
1. Cranking		.47 ±.12	—.05 ±.15	.43 ±.12	.22 ±.14	.20 ±.14	.10 ±.15	.41 ±.13	—.02 ±.15	.53 ±.11
2. Tapping			—.47 ±.12	.02 ±.15	.43 ±.12	.20 ±.14	.08 ±.15	.39 ±.13	.49 ±.11	.36 ±.13
3. Head turn				.25 ±.14	—.07 ±.15	.13 ±.15	.01 ±.15	.02 ±.15	—.13 ±.15	.17 ±.15
4. Arm raising					.47 ±.12	.34 ±.13	.03 ±.15	.15 ±.15	.04 ±.15	.25 ±.14
5. Body bend						.32 ±.14	.03 ±.15	.35 ±.13	.25 ±.14	.25 ±.14
6. Writing							.02 ±.15	.46 ±.12	.01 ±.15	.09 ±.15
7. Reading								.40 ±.13	—.13 ±.15	.11 ±.15
8. Counting									—.07 ±.15	.04 ±.15
9. Patting										.52 ±.11
10. Walking										
Average	.25 ±.14	.22 ±.14	—.02 ±.15	.22 ±.14	.25 ±.14	.20 ±.14	.07 ±.15	.24 ±.14	.11 ±.15	.26 ±.14

TABLE 9

COEFFICIENTS OF CORRELATION FOR GROUP *C* ON VOLUNTARY TEMPO ON THE SIXTH PRACTICE DAY (WEEKLY GROUP)

	1	2	3	4	5	6	7	8	9	10
1. Cranking		.59 ±.10	.18 ±.15	.36 ±.13	.30 ±.14	.26 ±.14	.16 ±.15	.27 ±.14	.61 ±.09	.34 ±.13
2. Tapping			—.12 ±.15	.23 ±.14	.20 ±.14	.39 ±.13	—.32 ±.14	.29 ±.14	.75 ±.07	.22 ±.14
3. Head turn				.80 ±.05	.60 ±.10	.13 ±.15	.01 ±.15	—.15 ±.15	—.22 ±.14	—.13 ±.15
4. Arm raising					.85 ±.04	.14 ±.15	—.25 ±.14	—.05 ±.15	.05 ±.15	—.06 ±.15
5. Body bend						.08 ±.15	—.31 ±.14	.12 ±.15	—.11 ±.15	.12 ±.15
6. Writing							—.20 ±.15	.37 ±.13	.49 ±.11	—.14 ±.15
7. Reading								.29 ±.14	—.47 ±.12	.25 ±.14
8. Counting									.31 ±.14	.22 ±.14
9. Patting										.14 ±.15
10. Walking										
Average	.34 ±.13	.20 ±.14	.12 ±.15	.23 ±.14	.21 ±.14	.17 ±.15	—.09 ±.15	.19 ±.15	.17 ±.15	.11 ±.15

from —.09±.15 to .34±.13. From inspection of individual correlations and from a comparison of columnar averages there appears to be some augmental effect, though not uniform, from *B-I* to *B-VI* (daily group). Comparison of *C-I* and *C-VI* (weekly group) fails to show even an erratic augmentation.

Instead of relying solely on inspection for testing the validity of the hypotheses, it was thought wise to employ a somewhat less subjective method of analysis, however crude, since inspectional interpretations are notoriously variable with the "personal equation" of the interpreter. Table 10 is the result of this further quantification.

TABLE 10

DIRECTION OF CHANGE IN NUMERICAL VALUE OF CORRELATION COEFFICIENTS WHEN CORRELATION TABLES FOR GROUPS *B* AND *C* ARE COMPARED

Groups compared	Positive *r*'s Change toward 1.0	Positive *r*'s Change toward —1.0	Negative *r*'s Change toward 1.0	Negative *r*'s Change toward —1.0	Unchanged
Experimental groups					
B-VI with *B-I* (daily)	22	14	7	0	2
C-VI with *C-I* (weekly)	13	23	5	2	2
Control comparison					
C-I with *B-I*	13	25	7	0	0

Here there are not only comparisons for changes in the direction of correlation values of the daily and weekly groups on the first and final practice days but control comparisons for the purpose of evaluating chance and non-experimental *r* fluctuations between the daily and weekly groups on the first day when experimental conditions are equated. Table 10 shows the direction of change of coefficients when two correlation tables are compared for the numerical values of their coefficients. Changes for positive and negative correlations are treated separately together with the direction of change —whether toward 1.0 or —1.0—so that all logical possibilities are covered. In this way the two hypotheses may be conveniently tested.

Positive and negative coefficients for the experimental groups should change in the direction of positive unity if Hypothesis I is valid, and all other coefficients may be counted as being in conflict with theory. For the daily group 29 *r* changes may be read from the table as favoring, and 16 as conflicting with, Hypothesis I. For the weekly group 18 *r* changes favor and 27 conflict with the hypothesis. The daily group is obviously different from the weekly group

in showing a greater degree of generality following repetition of performances.

For Hypothesis II all positive coefficients changing in the direction of positive unity and all negative coefficients moving in the direction of negative unity should be read as favoring and all others as being in contradiction to the hypothesis. Hypothesis II is disproved by the fact that for the daily group 22 *r* changes favor and 23 conflict with theory and for the weekly group 15 favor and 30 conflict with theory.

Evidently neither hypothesis is clearly substantiated for both groups and likely much of the fluctuation in correlational values in the experimental groups may be attributed to the small number of cases, quotidian variation, experimental error, and to various other irrelevant or uncontrolled factors. What positive evidence exists for either hypothesis comes from the daily group and favors Hypothesis I, but the augmental effect is neither uniform nor very large. The *r* augmentation in the daily group in contrast to its absence in the weekly group demonstrates the effect on the groups of the different temporal intervals between practice periods.

b. Sex differences for voluntary tempo. Since there appear to be no data in the literature on sex differences for voluntary tempo, it was felt that even with an inadequate number of cases the opportunity should not be ignored to search for consistent differences between the sexes. Because the daily and weekly groups for the first practice day were completely comparable, their results were pooled and tabulated for each sex separately, the number of cases being 20 for each sex. Differences for the 10 performances were negligible, the critical ratios being very low (.1 to .8) except for walking where women were significantly slower (*CR* of 2.9). The differences in walking rate may be discounted because the sexes are not comparable owing to the difference in footwear.

E. Conclusions

The conclusions stated should be understood as subject to the limitations imposed by the specific conditions of the experiments.

1. There was no indication of a unitary speed trait or factor which is characteristic of the voluntary spontaneous movements of an individual. Instead of such a generalized psychomotor trait rising out of a hypothetical personal tempo, the usual rate of voluntary

movement was more nearly determined by specific tasks or motor adjustments.

2. There was no indication of a unitary speed factor which is characteristic of all motor functions performed at a maximal rate of movement. The speed ranking of persons working at a maximal rate on one task was correlated with their speed ranking on another rate task for only a few of the intercorrelated functions.

3. In contrast to the specificity findings, there were a few exceptional individuals who were fairly consistent in their voluntary and maximal speed levels.

4. The hypothesis that correlations will be high between performances which are aprioristically similar, or which seem to possess more or less obvious common elements, was not found to be uniformly applicable. The hypothesis was more satisfactory, moreover, for maximal tasks than for the voluntary performances.

5. There was a low positive but statistically reliable relationship between voluntary and maximal rates of movement. The numerical value of the correlation coefficient varied considerably from one function to another.

6. On the basis of these results the apparent generality of voluntary tempo in everyday observation could not be attributed to habituation. Habituation, which would be expected to result from repetition of performances, failed uniformly to augment intercorrelations to a sufficient extent to yield results that would favor the theory of a generalized personal speed trait.

7. There was indication that the temporal intervals between practice periods had a differential effect on the intercorrelations obtained following practice. The correlations tended to rise when performances were repeated at short intervals of one day but this effect did not obtain for weekly repetitions.

8. When subjects rated themselves on a three-point scale for everyday speed level, the relationship between their self-estimate and actual measurements of voluntary rate of movement was in the expected direction and greater than chance. There was no indication of great accuracy, however, and there was considerable group overlapping. The differences between the Fast and Slow Groups were greater than between the Medium and Slow Groups, while the differences between the Fast and Medium Groups were frequently at variance with the self-rating and were usually lacking in statistical significance.

9. Sex differences for voluntary tempo were negligible.

The reader should be cautioned against too conclusive an interpretation of such specificity results in favor of personality specifists who maintain that traits and personality characteristics are entirely fictitious and should be regarded as biosocial rather than psychophysiological concepts—constructs or fictions in the thinking of persons in the immediate social environment. The well-grounded criticisms which have been leveled against the specificity doctrine when applied to the theory of personality structure are less relevant when specificity results are found for skills, speeds, and other "nonpersonality" characteristics. More individual congruency, especially for voluntary tempo, might be discoverable, or the correlations became more understandable, if there were knowledge available of all the socio-environmental and ontogenetic factors for each individual as well as his more ephemeral moods, sets, and motivation in the laboratory situation.

References

1. Adams, L. Consistency in speed on simple mental and motor tests. Unpublished master's essay, Columbia Univ., 1935. (Cited by Foley.)
2. Aikens, H. A., Thorndike, E. L., & Hubbell, E. Correlations among perceptive and associative processes. *Psychol. Rev.,* 1902, **9**, 374-382.
3. Allport, G. W., & Vernon, P. E. Studies in Expressive Movement. New York: Macmillan, 1933. Pp. 269.
4. Antipoff, H. Contribution à l'étude de la constance des sujets. *Arch. de Psychol.,* 1927, **20**, 177-190.
5. Atkinson, W. R. The relation of intelligence and mechanical speed to the various stages of learning. *J. Exper. Psychol.,* 1929, **12**, 89-112.
6. Baxter, M. F. An experimental study of the differentiation of temperaments on a basis of rate and strength. *Amer. J. Psychol.,* 1927, **38**, 59-96.
7. Beck, L. F. The relation of speed of reaction to intelligence. *Amer. J. Psychol.,* 1932, **44**, 793-795.
8. Bernstein, E. Quickness and intelligence. *Brit. J. Psychol. Monog. Suppl.,* 1924, **7**, 1-55.
9. Braun, F. Untersuchungen über das persönliche Tempo. *Arch. f. d. ges. Psychol.,* 1927, **60**, 317-360.
10. Bridges, J. W. An experimental study of decision types and their mental correlates. *Psychol. Monog.,* 1914, **17**, 1-72.
11. Brown, Wm. Some experimental results in the correlation of mental abilities. *Brit. J. Psychol.,* 1910, **3**, 296-322.
12. ————. The effects of "observational error" and other factors upon correlation coefficients in psychology. *Brit. J. Psychol.,* 1913, **6**, 223-238.

13. Burt, C. Experimental tests of general intelligence. *Brit. J. Psychol.*, 1909, **3**, 94-177.

14. ————. Experimental tests of higher mental processes and their relation to intelligence. *J. Educ. Ped.*, 1911, **1**, 93-112.

15. Buxton, C. E., & Humphreys, L. G. Critical experiment on the importance of physiological limits. *Psychol. Bull.*, 1934, **31**, 590-591.

16. ————. The effect of practice upon intercorrelations of motor skills. *Science*, 1935, **81**, 441-442.

17. Campbell, M. Individual differences in the speed of serial reaction of large muscle groups. *Psychol. Bull.*, 1930, **27**, 639-640.

18. ————. The "personal equation" in serial pursuit performance. *J. Appl. Psychol.*, 1934, **18**, 785-792.

19. Carothers, F. E. Psychological examinations of college students. *Arch. of Psychol.*, 1922, No. 46, 1-82.

20. Clark, J. R. The relation of speed, range and level to scores on intelligence tests. Unpublished thesis, Columbia Univ., 1924. (Cited by Dowd.)

21. Courthial, A., Van de Stadt, I., & Claparède, E. Rapidité et qualité. *Arch. de Psychol.*, 1932, **23**, 193-229.

22. Dowd, C. E. A study of the consistency of rate of work. *Arch. of Psychol.*, 1926, No. 84, 1-33.

23. Downey, J. E. The Will-Temperament and Its Testing. New York: World Book, 1923. Pp. 339.

24. Downey, J. E., & Uhrbrock, R. S. Reliability of the Group Will-Temperament tests. *J. Educ. Psychol.*, 1927, **18**, 26-39.

25. Dubois, P. H. A speed factor in mental tests. *Arch. of Psychol.*, 1932, No. 141, 1-38.

26. Easley, H. An attempt to isolate the factor of "attention." *Amer. J. Psychol.*, 1931, **43**, 202-215.

27. Eisenberg, P. A further study in expressive movement. *Charac. & Person.*, 1937, **5**, 296-301.

28. Farmer, E., & Chambers, E. G. A psychological study of individual differences in accident rates. London: Report No. 38, Ind. Fat. Res. Board, H. M. Stationary Office, 1926.

29. Farnsworth, P. R., Seashore, R. H., & Tinker, M. A. Speed in simple and serial action as related to performance in certain "intelligence" tests. *J. Genet. Psychol.*, 1927, **34**, 537-551.

30. Filter, R. O. An experimental study of character traits. *J. Appl. Psychol.*, 1921, **5**, 297-317.

31. Foley, J. P., Jr. Factors conditioning motor speed and tempo. *Psychol. Bull.*, 1937, **34**, 351-397.

32. Frischeisen-Köhler, I. Das persönliche Tempo: Eine erbbiologische Untersuchung. Berlin: G. Thieme, 1933. Pp. 63.

33. ————. The personal tempo and its inheritance. *Charac. & Person.*, 1933, **1**, 301-313.

34. Garrett, H. E. Statistics in Psychology and Education. New York: Longmans, Green, 1926. Pp. 317.

35. ————. The relation of tests of memory and learning to each other and to general intelligence in a highly selected group. *J. Educ. Psychol.*, 1928, **19**, 601-613.

36. GARRISON, K. C. An investigation of some simple speed activities. *J. Appl. Psychol.,* 1929, **13**, 167-172.

37. ————. Further studies in various types of speed performances as related to mental ability. *J. Genet. Psychol.,* 1929, **36**, 344-349.

38. GATES, A. I. An experimental and statistical study of reading and reading tests. *J. Educ. Psychol.,* 1921, **32**, 303-314, 378-391, 445-464.

39. GATES, A. I., & SCOTT, A. W. Characteristics and relations of motor speed and dexterity among young children. *J. Genet. Psychol.,* 1931, **39**, 423-453.

40. GILBERT, E. C. The constancy of the speed factor in the performance of various tasks. Unpublished thesis, Harvard Univ., 1926. (Cited by Foley.)

41. GUTTMANN, A. Das Tempo und seine Variationsbreite. *Zsch. f. angew. Psychol.,* 1931, **40**, 65.

42. HANSEN, C. F. Serial action as a basic measure of motor capacity. *Psychol. Monog.,* 1922, **31**, 320-382.

43. HARRISON, R., & DORCUS, R. M. Is rate of voluntary bodily movement unitary? *J. Gen. Psychol.,* 1938, **18**, 31-39.

44. HART, B., & SPEARMAN, C. Mental tests of dementia. *J. Abn. Psychol.,* 1914, **9**, 217-264.

45. HOLLINGWORTH, H. L. Correlation of abilities as affected by practice. *J. Educ. Psychol.,* 1913, **4**, 405-414.

46. ————. Individual differences before, during, and after practice. *Psychol. Rev.,* 1914, **21**, 1-8.

47. HÜBEL, W. Über psychische Geschwindigkeiten und ihre gegenseitigen Beziehungen. *Zsch. f. Psychol.,* 1930, **35**, 447-496.

48. HUNSICKER, L. M. A study of the relationship between rate and ability. Columbia University: *Teach. Coll. Contrib. Educ.,* 1925, No. 185. Pp. 52.

49. JONES, E. S. The Influence of Age and Experience on Correlations Concerned with Mental Tests. New York: Warwick & York, 1917. Pp. 89.

50. KENNEDY, M. Speed as a personality trait. *J. Soc. Psychol.,* 1930, **1**, 286-299.

51. KRUEGER, F., & SPEARMAN, C. Die Korrelation zwischen verschiedenen geistigen Leisungsfähigkeiten. *Zsch. f. Psychol.,* 1906, **44**, 50-114.

52. LAMBERT, M., & LANIER, L. H. Race differences in speed of reaction. *J. Genet. Psychol.,* 1933, **42**, 255-297.

53. LANIER, L. H. The interrelations of speed measurements. *J. Exper. Psychol.,* 1933, **17**, 371-399.

54. LASURSKI, A., & RUMJANZEW, —. *Bericht in der Gesellschaft für normale und pathologische Psychologie,* April, 1909. (Cited by Lewitan.)

55. LAU, E. Über die Veränderlichkeit des personlichen Tempo. *Psychotechn. Zsch.,* 1928, 101. (Cited by Courthial, Van de Stadt, and Claparède.)

56. LAUER, A. R. Personal "tempo" or rhythm. *Proc. Ia. Acad. Sci.,* 1933, 40, 192-193. (*Psychol. Abst.,* 1935, **9**, No. 3192.)

57. LEEDY, J. L. The relation of speed of reaction to basal metabolism and blood pressure. Unpublished thesis, Vanderbilt Univ., 1931. (Cited by Lanier.)

58. LEMMON, V. W. The relation of reaction time to measures of intelligence, memory, and learning. *Arch. of Psychol.*, 1927, No. 94, 1-39.

59. LEWIS, A. L. Comparison of the times of simple reactions and of free-arm movements in different classes of persons. *Psychol. Rev.*, 1897, **4**, 113-114.

60. LEWITAN, C. Untersuchungen über das allgemeine psychomotorische Tempo. *Zsch. f. Psychol.*, 1927, **101**, 321-376.

61. LINE, W., & KAPLAN, E. The existence, measurement and significance of a speed factor in the abilities of public school children. *J. Exper. Educ.*, 1932, **1**, 1-8.

62. LONGSTAFF, H. P., & PORTER, J. P. Speed and accuracy as factors in objective tests in general psychology. *J. Appl. Psychol.*, 1928, **12**, 636-642.

63. MCCOLLOM, I. N. Analysis of factors determining individual differences in speed at simple repetitive motion. Unpublished thesis, Univ. of Oregon. (Cited by Buxton and Humphreys.)

64. MCFARLAND, R. An experimental study of the relationship between speed and mental ability. *J. Gen. Psychol.*, 1930, **3**, 67-97.

65. MCNEMAR, Q. Practice and "general" motor ability. *J. Gen. Psychol.*, 1936, **14**, 464-466.

66. NEUMANN, E. Vorlesungen zur einführung in die Experimentelle Pädadogik und ihre psychologischen Grundlagen. Berlin: Engelmann, 1913. Pp. 800.

67. MUSCIO, B. Motor capacity with special reference to vocational guidance. *Brit. J. Psychol.*, 1922, **13**, 157-184.

68. ODELL, C. W. Statistical Method in Education. New York: Appleton-Century, 1935. Pp. 457.

69. PATERSON, D. G., ELLIOTT, R. M., ANDERSON, L. D., & HEIDBREDER, E. Minnesota Mechanical Abilities Test. Minneapolis: Univ. Minnesota Press, 1930. Pp. 586.

70. PERRIN, F. A. C. An experimental study of motor ability. *J. Exper. Psychol.*, 1921, **4**, 24-56.

71. PIERCE, A. W. A study of speed in certain reflex and voluntary reactions. Unpublished thesis, Vanderbilt Univ., 1931. (Cited by Lanier.)

72. REAM, M. J. The tapping test: a measure of motility. *Psychol. Monog.*, 1922, No. 140, 293-319.

73. REYMERT, M. L. The personal equation in motor capacities. *Scand. Sci. Rev.*, 1923, **2**, 177-222.

74. ROUNDS, G. H. Is the latent time in the Achilles tendon reflex a criterion of speed in mental reactions? *Arch. of Psychol.*, 1928, No. 95, 1-91.

75. SEASHORE, R. H. Individual differences in motor skills. *J. Gen. Psychol.*, 1930, **3**, 38-66.

76. SEASHORE, S. The aptitude hypothesis in motor skills. *J. Exper. Psychol.*, 1931, **14**, 555-561.

77. SISK, J. K. The inter-relations of speed in simple and complex responses. *George Peabody College for Teachers, Contrib. Educ.*, 1926, No. 23. Pp. 48. (Cited by Foley.)

78. SPEARMAN, C. The Abilities of Man. New York: Macmillan, 1927. Pp. 415.

79. STRICKLAND, G. I. The influence of practice on the correlation of abilities. *J. Educ. Psychol.,* 1918, **9**, 393-399.

80. SUTHERLAND, J. D. The speed factor in intelligent reactions. *Brit. J. Psychol.,* 1934, **24**, 276-294.

81. TINKER, M. A. The significance of speed in test response. *Psychol. Rev.,* 1931, **38**, 450-454.

82. TINKER, M. A., IMMS, A. J., & SWANSON, C. A. Card-sorting as a measure of learning and serial action. *J. Exper. Psychol.,* 1932, **15**, 206-211.

83. TRAVIS, L. E., & YOUNG, C. W. The relation of electromyographically measured reflex times in the patellar and Achilles reflexes to certain physical measurements and to intelligence. *J. Gen. Psychol.,* 1930, **3**, 376-400.

84. TROW, W. C. Trait consistency and speed of decision. *Sch. & Soc.,* 1925, **21**, 538-542.

85. UHRBROCK, R. S. An analysis of the Downey Will Temperament tests. Columbia University: *Teach. Coll. Contrib. Educ.,* 1928, No. 296. Pp. 78.

86. WALTERS, F. C. A statistical study of certain aspects of the time factor in intelligence. Columbia University: *Teach. Coll. Contrib. Educ.,* 1927, No. 248. Pp. 82.

87. WISSLER, C. The correlation of mental and physical tests. *Psychol. Monog.,* 1901, **3**, 1-62.

88. WOODWORTH, R. S. Le Mouvement. Paris: Doin, 1903. Pp. 421.

89. WU, C. F. Personal tempo and speed in some rate tests. *J. Test.,* (Chinese), 1934, **2**, 85-94. (*Psychol. Abst.,* 1935, **9**, No. 1709.)

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